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(56) Documents Cited
GB 2247812 A GB 2243271 A US 5228058 A
US 5199047 A US 5185764 A

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(54) A Digital cellular mobile radio receiver

(57) The digital cellular mobile radio receiver comprises a channel estimator 4 which receives on an input line 2, digital samples of I and Q baseband data in the form of a transmission burst. The transmission burst is also applied to an input of an equalising filter 8. The channel estimator generates an output signal which is an estimate of the impulse response h(n). This is applied to a filter response calculator 6 which generates an impulse response signal c(n) which is applied to the equalising filter 8. The equalising filter 8 convolves the signals c(n) with the transmission burst and cancels any inter symbol interference. The output of the filter 8 is applied to the input of a demodulator 10 from which output signals are generated on an output line 12. The receiver provides simple equalisation of a received digital sequence and high speed detection of the received transmission bursts.

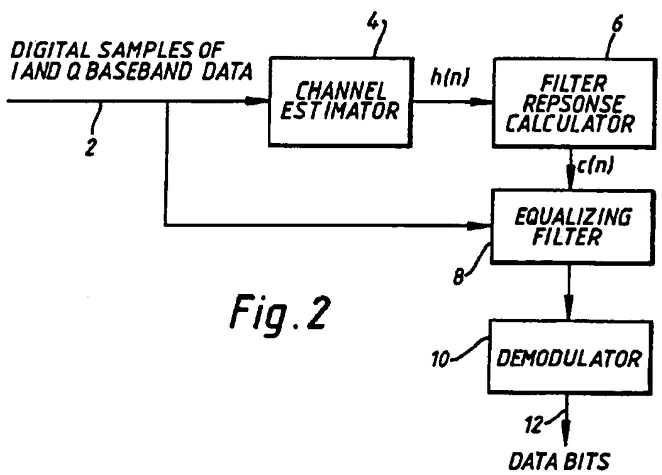

Fig. 2

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

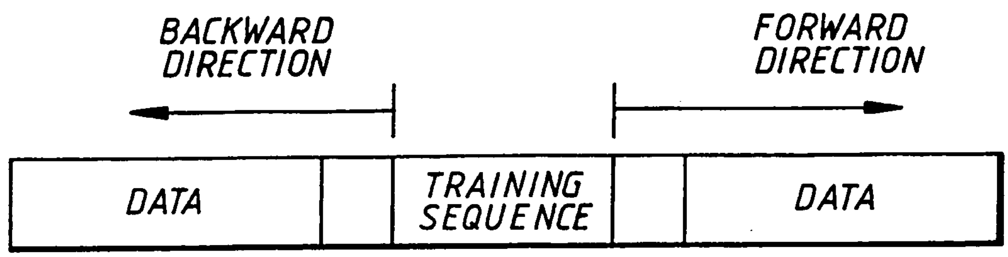
BACKWARD DIRECTION
FORWARD DIRECTION
DATA
TRAINING SEQUENCE
DATA

Fig.1

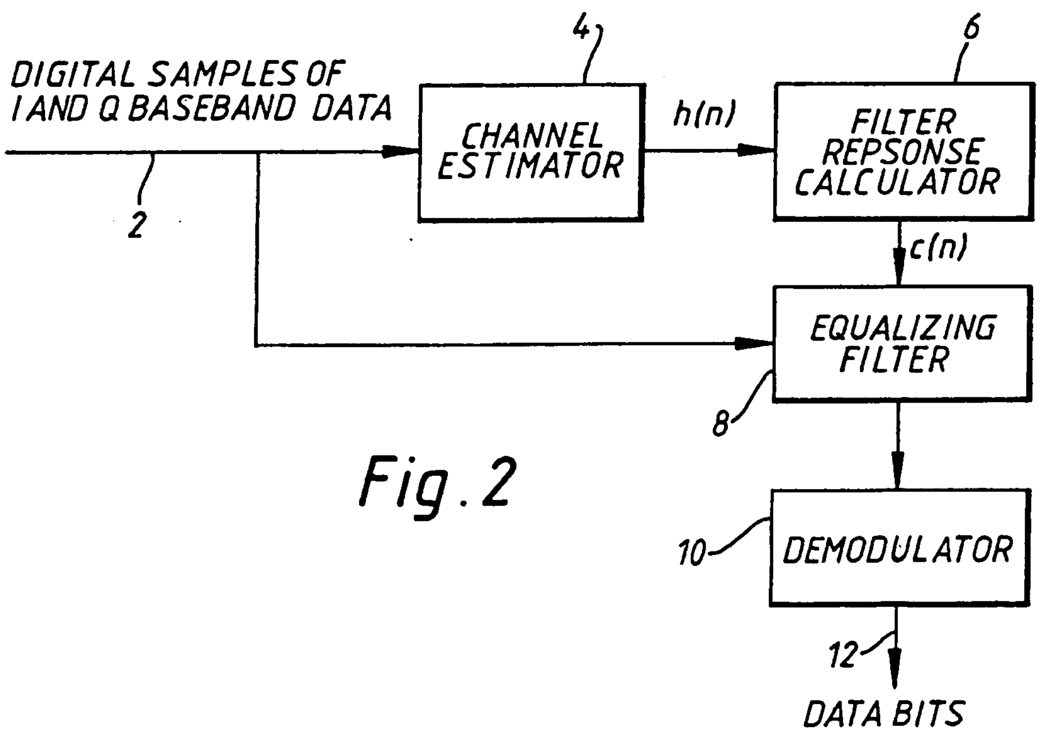
DIGITAL SAMPLES OF I AND Q BASEBAND DATA
2
4
CHANNEL ESTIMATOR
h(n)
6
FILTER REPSONSE CALCULATOR
c(n)
EQUALIZING FILTER
8
10
DEMODULATOR
12
DATA BITS

Fig.2

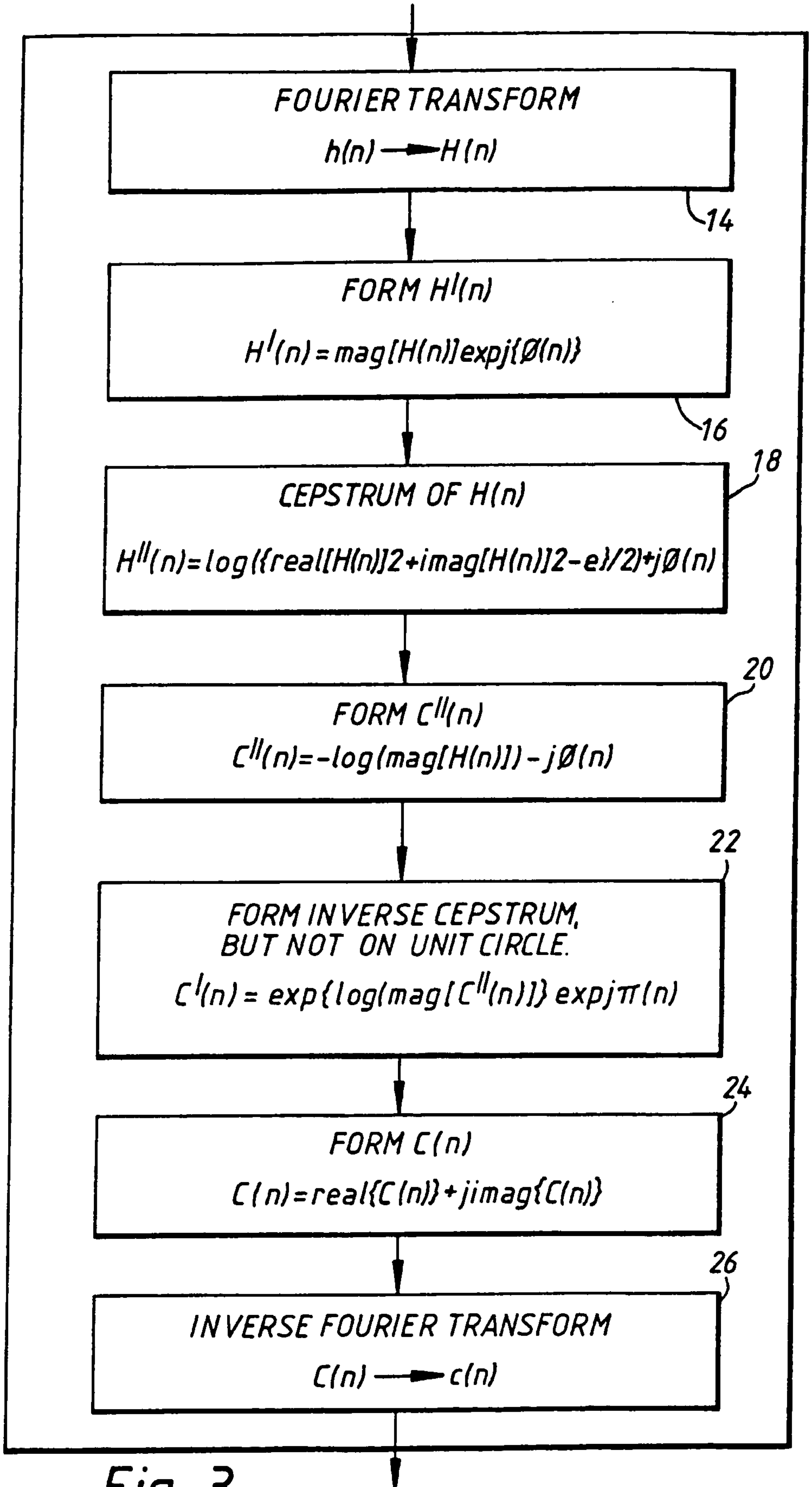

Fig. 3

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A DIGITAL CELLULAR MOBILE RADIO RECEIVER

The present invention relates to a digital cellular mobile radio receiver including a filter arrangement that is able to efficiently equalise a digital transmission burst.

Receivers that are used in time decision multiple access (TDMA) mobile radio systems, require the use of an equaliser to mitigate against the time dispersive nature that is typical of the mobile radio propagation path, and which causes inter symbol interference.

The demand for high data rate services in future TDMA mobile radio systems, will require the reception and equalisation of multiple transmission bursts. Equalisers such as Maximum Likelihood, or Near Maximum Likelihood Sequence Estimators are computationally intensive and therefore involve expensive implementation and require significant processing time to equalise a transmission burst. The later factor becomes more important when attempting to equalise multiple transmission bursts within a TDMA frame.

In present second generation and third generation digital mobile radio systems, information is transported over the air interface in bursts. A necessary part of the detection process for these bursts is the transmission of an embedded training sequence. By cross-correlating this embedded sequence against a replica at the receiver, the channel impulse response is estimated and synchronisation is obtained. To minimise the effect of frequency dispersion, the training sequence should be embedded

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in the centre of the transmission bursts, as shown in Figure 1, as used in the global systems for mobile communications.

For optimal equalisation of the transmission burst, the equaliser should run from the centre outwards. Thus the later half of the transmission burst is equalised in the forward time, whereas the former half is equalised going backwards in time. This feature must be employed where phase tracking is employed across the burst during the equalisation process, as would be required in high speed mobile applications. In addition, when there is a requirement to transmit more sensitive information in the transmission burst, this is placed on either side of the mid amble where the channel impulse response estimate is more accurate. Again this requires that the transmission burst is processed both forwards and backwards in time, from the training sequence outwards.

An object of the present invention is to provide a digital cellular mobile radio receiver including a equaliser of reduced complexity.

According to the present invention there is provided a digital cellular mobile radio receiver including a baseband channel arranged to receive a transmission burst, channel estimation means, and demodulation means for providing an output signal from the receiver, characterised by calculation means for receiving a channel estimation signal from the channel estimation means and arranged to calculate an impulse response, filter means for receiving the transmission burst and the impulse response, and arranged to convolve the transmission burst with the impulse

response to generate an output signal, devoid of inter symbol interference, which is fed to an input of said demodulation means.

The calculation means performs a Fourier transform of the channel impulse response, forms a Cepstrum, forms an inverse Cepstrum and forms a discrete frequency domain response.

An embodiment of the present invention will now be described with reference to the accompanying drawings, wherein:

FIGURE 1 shows a transmission burst with a training sequence embedded in the middle of the burst,

FIGURE 2 shows a block diagram of a digital cellular mobile radio receiver, and

FIGURE 3 shows a flow diagram of the steps performed by the filter response calculator.

Referring to Figure 2, a block diagram of a digital cellular mobile radio receiver is shown. The receiver is used for the reception, equalisation and demodulation of a transmission burst in which a known training sequence is embedded.

The transmission burst is received on the input line 2 and is fed to the channel estimator 4 and an equalising filter 8. The channel estimator 4 is connected to an input of a filter response calculator 6, the output of which is connected to a further input of the equalising filter 8. The output of the equalising filter 8 is connected to an input of a demodulator 10, the output 12 of which generates output data bits.

The training sequence is used by the channel estimator 4, to estimate channel impulse response denoted by $h(n)$, where $n = 0$ to $L-1$ and L is the length of the channel impulse response. The

channel impulse response is then passed to the filter response calculator 6, which processes h(n), and generates an impulse response c(n). The impulse response c(n) is passed to the equalising filter 8 which performs the convolution process with the received transmission burst. After this point the inter symbol interference caused by both the transmission channel and the transmit and receive filters is cancelled. This enables a simple demodulator 10 to be used to perform the inverse signal constellation mapping of the modulator.

For example, considering a system in which the modulation scheme is a Binary Offset QAM, after the signal has been convolved, the transmit and receive filter impulse responses will have been removed, together with the inter symbol interference caused by the transmission channel itself. After this point, the demodulator 10 can be implemented by simply multiplying the complex samples of the data stream by a rotating vector (expj$\{\pi n/4\}$, with n = 0, 1, 2, 3), and subsequently using a threshold detector to determine the data bits which are output on line 12.

The filter response calculator 6 will now be described with reference to Figure 3. In Figure 3, element 14 forms the discrete Fourier transform of the channel impulse response, H(n). The element 16 places this discrete Fourier response into magnitude and phase components, such that the Cepstrum may be formed by the element 18. However, the Cepstrum of H(n), is not calculated on the unit circle, but is calculated just within the unit circle. This is done by introducing a predetermined constant (e) into the

calculation of the magnitude. This is required because a characteristic of mobile radio channels is that they have nulls in the frequency response. To prevent the gain of the equalising filter becoming extremely large, and therefore enhancing the noise in the received signal, the Cepstrum is evaluated at a point just inside the unit circle.

The Cepstrum of the equalising filter 8 is formed by the element 20, by taking the negative of both real and imaginary parts of the Cepstrum of H(n). The element 22 forms the inverse Cepstrum of the desired filter response, and the element 24 forms the real and imaginary part of the discrete frequency domain response C(n). The element 26 forms the time domain response for the equalising filter. The convolutional of the equalising filter with the received transmission burst may be done in either time or frequency domains. As such the element 26 may not be required and so may be omitted in the case where the convolution is performed in the frequency domain.

The digital receiver as described has the following advantages. It provides a simple equalisation of a received digital sequence. The simplicity of the calculation provides for the high speed detection (demodulation and equalisation) of the received transmission bursts, and the implementation of the receiver is relatively simple.

It will be readily appreciated by those skilled in the art that various modifications are possible within the spirit and scope of the present invention. For example, trellis coded modulation may be used.

CLAIMS

1. A digital cellular mobile radio receiver including a baseband channel arranged to receive a transmission burst, channel estimation means, and demodulation means for providing an output signal from the receiver, characterised by calculation means for receiving a channel estimation signal from the channel estimation means and arranged to calculate an impulse response, filter means for receiving the transmission burst and the impulse response, and arranged to convolve the transmission burst with the impulse response to generate an output signal, devoid of inter symbol interference, which is fed to an input of said demodulation means.

2. A digital cellular mobile radio receiver as claimed in Claim 1, wherein the calculation means performs a Fourier transform of the channel impulse response, forms a Cepstrum, forms an inverse Cepstrum and forms a discrete frequency domain response.

3. A digital cellular mobile radio receiver as claimed in Claim 2, wherein the calculation means forms a time domain response for the filter means.

4. A digital cellular mobile radio receiver as claimed in Claim 2 or Claim 3, wherein the Cepstrum is formed by calculation of a magnitude and introducing a predetermined constant into the calculation.

5. A digital cellular mobile radio receiver substantially as hereinbefore described with reference to Figures 2 and 3 of the accompanying drawings.

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Patents Act 1977
Examiner's report to the Comptroller under Section 17
(The Search report)

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Relevant Technical Fields

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(ii) Int Cl (Ed.5) H04B 7/005; H04L 25/03, 27/01, 27/22

Search Examiner
K WILLIAMS

Date of completion of Search
13 JUNE 1994

Databases (see below)
(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii) ONLINE DATABASE: WPI

Documents considered relevant following a search in respect of Claims :-
1-5

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document

Category	Identity of document and relevant passages		Relevant to claim(s)
A	GB 2247812 A	(MOTOROLA) see page 8 onwards	1
A	GB 2243271 A	(GEC MARCONI) see pages 1 and 2	1
X	US 5228058	(NEC CORP) see Claim 2 and Figure 4	1
X	US 5199047	(U.S. PHILIPS) see Figures 1, 3	1
X	US 5185764	(U.S. PHILIPS) see Figure 2	1

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).

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